Developing A Research Agenda for Ubiquitous Computing in Schools[1]

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Introduction

A major barrier to the use of computers in schools has been the difficulty of getting access to them whenever and wherever needed (Adelman et al., 2002; U.S. Department of Education Policy and Program Studies Service, 2003). But a new and different reality is evident in the thousands of elementary and secondary school classrooms where every student has his or her own computer—a situation that seems to be a harbinger of things to come, as computers become smaller, cheaper, and more ubiquitous every year. The state of Maine now provides laptops and wireless Internet access in public schools to all 7th and 8th graders, and Henrico County, Virginia supports wireless Internet access via laptops to more than 23,000 students and teachers in grades 6 through 12. Michigan has provided more than 80,000 teachers with computers and is expanding its initiative to include many thousands of students. Texas, New Hampshire, and Vermont are experimenting with laptop initiatives. Hundreds of independent and public schools also support so-called 1:1 computing (www.learningwithlaptops.com). Meanwhile, thousands of teachers are experimenting with class sets of less expensive computing devices, such as Palm Pilots, AlphaSmarts, and Danas (Soloway et al., 2001; Vahey & Crawford, 2002).

Although research on 1:1 computing in a limited number of schools is about a decade old (e.g., research in Union City, NJ dates from the early 1990s), there has not yet been enough research to keep pace with policymakers' and practitioners' calls for guidance and for reliable information about what happens when every student has a computer. This situation should not be surprising given the fact that large-scale implementation of 1:1 computing in schools is so new (e.g., Henrico County's initiative only started in 2001-2002). One result is that reviews of research on 1:1 computing typically provide relatively "soft" evidence for their conclusions. Research has not yet provided policymakers with enough hard evidence of the benefits and costs of 1:1 computing to help them determine if the initiatives are worth what they cost, nor has research established the mix of factors that make 1:1 computing more or less effective.

In light of our relative ignorance about ubiquitous computing, there is a need for more research. However, there is little doubt that some studies will be more valuable than others. Given the large number of possible research questions, a conversation about priorities may be useful—for researchers, educators, policymakers, potential sponsors of the research, and others.

A Research Framework

A research framework can help to organize people's thinking and thus guide the development of a research agenda. A number of such frameworks for research on 1:1 computing are available (e.g., Metiri Group, 2002; Kerr, Pane, & Barney, 2003). The particular research framework presented here is based in part on earlier frameworks and in part on discussions that have been carried out as one component of a National Science Foundation sponsored project in which a consortium of researchers from various institutions, each of which is involved in studying 1:1 computing, are collaborating to share findings and discuss planned activities.[2]

[2] The consortium's communications, either face-to-face or via email, have included researchers from SRI International, EDC, the Metiri Group, the University of Virginia, the University of Nevada at Las Vegas, Rockman Et Al, Kent State University, the RAND Corporation, Boston College, and the Universities of Maine and Southern Maine. See ubiqcomputing.org for more information about the consortium.

The research framework shown in Figure 1 is intended to be used particularly at the system level, meaning schools, districts, or whole states (rather than for classroom-level research). Because 1:1 initiatives now involve thousands and in some cases tens of thousands of participants, it is particularly appropriate to conduct research at the system level.

-- Insert Figure 1 about here --

Critical Features of 1:1 Initiatives

The left-hand box in Figure 1 represents the critical features for 1:1 initiatives. Not all 1:1 initiatives are the same, so understanding the critical features that distinguish them is important. For example, we do not expect 1:1 initiatives that use handheld computers to necessarily have the same impacts or experience the same implementation challenges as those initiatives that use laptops, or as those that rely on thin clients. Thus, the *technology used* is one of the important characteristics of a 1:1 initiative. Within that same box in Figure 1, *setting* refers to the location of the 1:1 initiative, such as a school, school district, or state. Each setting has particular demographic, political, and other characteristics (e.g., state curriculum standards and assessments) that may affect the initiative. Maine, for example, is a state with strong traditions of local control, and those traditions, as well as the state-wide nature of the initiative, and the demographics of Maine, all affect the Maine Learning Technology Initiative (MLTI). Ubiquitous computing initiatives also differ in terms of their *implementation plans*, such as whether teacher professional development for integrating technology is an important component of the initiative (in some cases it is not), and, if it is, how it will be done. Finally, policymakers initiating a 1:1 initiative may do so with a particular vision in mind, i.e. *goals and objectives*, and these, too, are part of the characteristics of the initiative. For example Angus King, the former Governor of Maine who initiated the state's laptop initiative, explained that an important goal was to increase the economic competitiveness of Maine—a state that historically has had little high-technology business and industry (Lemke & Martin, 2003).

Ultimate Outcomes

The right-hand box in Figure 1 represents the most significant expected goals or outcomes of 1:1 computing. For the majority of people, the most important outcomes of 1:1 computing are the intended impacts *on students and their learning*. These impacts can take a variety of forms, such as changes in test scores, the acquisition of "21st century skills," such as learning to use computer-based tools (Partnership for 21st Century Skills, 2003), or increased student motivation and attendance.

In Maine, *economic competitiveness* is also among the expected outcomes, as noted above. Therefore, research about the impacts of Maine's laptop initiative might focus on this desired outcome, if a suitable research methodology can be found.

Policymakers in Maine, in Henrico County, Virginia, and in many other 1:1 computing sites are also concerned about increasing equity of access to information and computing, i.e., narrowing the "*digital divide*." Research questions about reducing the digital divide are appropriate for many 1:1 initiatives. Data show that in some places with laptop initiatives,

thousands of students are being provided access to computers, information, and services that they did not have before (unpublished data, Silvernail & Harris, 2003).

In this framework, the ultimate goals or outcomes of 1:1 initiatives are intentionally restricted to a small number. One reason for doing so is to signal that research focusing on these few goals of 1:1 computing—student learning, equity, and economic competitiveness—may be viewed by many people, including some sponsors of research, as especially valuable.

However, research that focuses on the ultimate outcomes of 1:1 computing is not the only high priority. Proponents of the most rigorous, experimental studies focusing on student achievement agree that understanding *why* certain outcomes occur is important (Myers & Dynarski, 2003). In other words, research needs to focus on *how* teachers and students work with computers, not just the results of their efforts.

Interactions and Intermediate Outcomes

The middle box in Figure 1 represents the *how*—that is, implementation of a 1:1 initiative, including the interactions of parents, administrators, teachers, and students with the technology. As a result of these interactions, a 1:1 initiative will have a series of intermediate outcomes. Although some of these outcomes may be considered desirable in themselves, such as greater parent involvement, or new patterns of teaching that result when 1:1 initiatives are implemented, they are labeled as intermediate outcomes in this framework to indicate that they are considered means to more important ends, such as improving student achievement.

Six sets of interactions and intermediate outcomes are identified in the framework. *Teaching and instruction* refers to how teachers make use of 1:1 computing and the impacts of the initiative on curriculum and classroom activities. *School leaders* indicates the actions and changing roles and behaviors of administrators and other school leaders, which might range from being responsible for hiring new staff, to answering questions from parents and the press. *Infrastructure and support* refers to both physical impacts (e.g., maintaining devices and networks) and human infrastructure (e.g., new positions, such as for technical support and / or instructional technology coordinators). *Schools and systems* refers to impacts at the state, district, and school level, such as changes in school culture, or in district and state policies. *School – community relations* refers to impacts on parents and the community and any changes in the roles of students in these contexts. Finally, *costs and funding* indicates a topic that cuts across several of the others but deserves special attention due to the fact that finding funds to support 1:1 computing is one of the important challenges that faces policymakers, and yet is an area in which little information is currently available. This set of six topics is intended to be comprehensive.

Identifying Research Questions

For each of the many topics shown in Figure 1, sets of research questions can be developed. For example, focusing on the topic of *teaching and instruction*, shown in the Interactions and Intermediate Outcomes box in Figure 1, we can ask such questions as:

- What is the impact on teaching behaviors, the curriculum, and instructional practices?
  - For what sorts of tasks do *teachers* use technology, and in what subjects?
  - For what sorts of tasks are *students* asked to use technology, and in what subjects?

- How often and for how long do teachers and their students use technology?
- How does classroom culture change (e.g., relationships between teacher and students)?

- Do teachers implementing a 1:1 initiative have the technical skills they need to use the technology effectively? Are they engaged in professional development to learn needed skills and strategies?
- What is the impact on teachers' interactions with one another and on teacher communities? Are teachers sharing what they are learning?
- What digital resources are used? What are the most promising instructional applications of technology (e.g., specific pieces of software, or Web sites) used within a given 1:1 initiative?
- What are facilitators and barriers to using the 1:1 computing devices for teaching?

To take another example, a set of research questions can be developed for *students and their learning*, shown in the Ultimate Outcomes box in Figure 1. These questions include:

- What are the impacts of the 1:1 initiative on measures of student achievement, broken out by age and by subject? And what are the impacts on the academic achievement of different student sub-groups (e.g., special education students)?
- What are the impacts on students' 21st century skills, such as their fluency with information technology? What are the impacts on students' responsibility for directing their own learning?
- What are the impacts on students' engagement with school, their motivation and attendance?
- What are the impacts on students' uses of the technology? For example, are students allowed to take their computers home? If so, how often do students (and which students) take the computers home, and how do they use them at home?

For any particular 1:1 initiative, which can be described by a particular set of critical features identified in the Critical Features box in Figure 1, dozens of interesting research questions can easily be generated using this framework, using the topics in the middle and right-hand boxes as takeoff points (see http://ubiqcomputing.org/eval_materials.html). There are many more questions than are likely to be answered well by any single study—particularly if the most rigorous research methods are used, since these can be both costly and time consuming.

However, even focusing on the many research questions associated with implementation and outcomes is just a beginning, because researchers are also interested in understanding the effects of varying the critical features of 1:1 initiatives. Does it matter whether the initiatives use handheld devices or laptops, which pieces of software are loaded on the computers, how teacher professional development is conducted as part of the initiative, how large the class sizes are, whether the setting is a single district or an entire state? Are the impacts of a 1:1 initiative different depending on what grade levels are targeted, or whether the initiative takes place within a large inner city or a rural area? Certainly, the critical features of the initiatives *do* matter, but if one were to try comparing different varieties of 1:1 initiative "head to head" in the same study,

one might need to conduct dozens of studies and answer hundreds of research questions. Faced with such a large set of choices, setting priorities is essential.

Developing a Research Agenda

Creating a research agenda depends on considering what we already do and do not know, and for this purpose research reviews can be especially useful (e.g., Penuel et al., 2002; Kerr et al., 2003; Rockman, 2003). Developing a research agenda also means considering questions deemed important by educators, policymakers and sponsors of research, identifying research questions for which answers potentially can affect large expenditures of public funds, finding and studying variables that are especially sensitive to change (that is, critical features for which a little difference can create a big impact), and so forth. Practical considerations are also a factor in creating a research agenda. For example, some studies are conceptually interesting but not feasible, e.g., because they are too expensive.

The process of establishing a research agenda should involve a community of researchers, sponsors of research, policymakers, educational leaders, and others involved in conversation about what is most important to study. This article is one contribution to a larger conversation.

Students and Their Learning

Increasing student achievement is clearly the most important goal for adopting 1:1 computing. Documenting impacts of 1:1 computing on achievement in a rigorously designed study is, in a sense, the "holy grail" for researchers in this field. As a result, studies focused on student learning deserve a high priority.

Only a few schools have reported that 1:1 computing has contributed to a major change in student performance. The W.L. Parks middle school in Atlanta is one such school. There, the percentage of students passing state tests increased by double digits in just a few years (Robinson, 2003). However, this school's program consisted of more than providing laptops to students and teachers. A dynamic principal and his young staff also used particular software products and a focus on project-based learning in an effort to go from "worst to first." It would be useful to see if this school's experience can be sustained and also replicated.

The typical experience of schools in 1:1 computing initiatives is quite different. One researcher experienced in researching 1:1 computing recently wrote:

> We consistently find substantive impacts on teaching and learning, on teachers and students, yet we continue to have difficulty tying full-time access to computers to the outcomes of standardized tests currently in use. (Rockman, 2003)

There could be many reasons why this is true. One likely possibility is that because choices about how to use technology are often left to individual students and teachers (rather than being focused on particular learning goals across an entire state, district, or school, as was the case at W.L. Parks), impacts on student achievement are weak and scattered. Studies of focused interventions involving 1:1 computing will be useful to establish what is possible.

For example, the U.S. Department of Education is beginning a set of studies of discrete education software products—e.g., products aimed at teaching reading in the early elementary grades—to find out whether they are effective in increasing student achievement across a

number of schools and school systems (U.S. Department of Education, 2003b). These studies will be conducted as randomized field trials, which can provide strong evidence of effectiveness. Although the use of discrete software products does not necessarily depend on every student having a computing device, if policymakers learn from studies such as these that XYZ software is effective in raising student achievement (particularly in schools like theirs), they will have a much stronger incentive to license and use that software. Evidence gathered from these and similar studies is likely to influence views of whether and how technology impacts achievement and, in turn, whether and how 1:1 initiatives use particular products.

However, many teachers and students involved in 1:1 computing use tool software (e.g., word processors, spreadsheets) and freely available Web sites rather than proprietary products aimed at teaching particular skills and knowledge. Understanding the impacts of 1:1 computing in such situations, where the intervention is *not* primarily one particular piece of software, but is nonetheless focused on key learning goals, is as important as studying commercial products, because for many teachers and students this is probably the most common experience. A few such studies are under way. For example, the U.S. Department of Education is supporting a new study in Maine that focuses on teaching middle school mathematics in a technology-rich environment using freely available applets, i.e. small content-focused programs available through a Web browser (U.S. Department of Education, 2003a; Trotter & Borja, 2004). A randomly selected group of experimental teachers will be provided with intensive professional development that focuses on the use of applets to teach algebraic thinking and other skills in the Maine curriculum. Outcomes to be studied include student test scores, as well as changes in teachers' content knowledge and pedagogy.

Designing and conducting studies that involve randomized trials and multiple measures is difficult, costs a lot of money, and takes a long time. There are multiple subjects and many grade levels on which researchers might focus their attention, as well as countless pieces of discrete software, or other sets of tools (such as Web-based applets) or procedures (such as particular ways to use word processors to teach writing), that could be used by teachers and students to improve student achievement. Care needs to be taken to select the most promising interventions to study, focusing on instances where the technology is both powerful and well-linked to state and local goals for curriculum and instruction.

Definitions of important student outcomes also need to be carefully examined. As a result of the No Child Left Behind Act, state testing in core subjects now carries higher stakes than in the past; nonetheless, other student outcomes besides test scores also are important, including 21st century skills. It seems clear that large numbers of high school students are becoming more proficient at computer networking, computer graphics, basic and advanced programming, Web design, and a variety of other technology skills highly valued in the labor force. Documenting whether and how 1:1 initiatives contribute to students' technology skills is an area in which more research is needed. Also, 1:1 initiatives may increase students' capacity to learn independently or result in other important outcomes besides higher test scores.

The fact that a number of states are beginning to conduct high stakes testing using computers raises new opportunities to expand the nature of what is tested. For example, just as students are allowed to use calculators for certain local, state, and national tests, it may become feasible to test writing using word processors, or to test students' technology proficiency not with paper and pencil but by using computers directly, as North Carolina has already done

(Public Schools of North Carolina State Board of Education, 2002). Promoting students' "technology proficiency" is one goal of the No Child Left Behind Act, and more discussion and research are needed to understand how this goal is interpreted and what contributions to reaching the goal, if any, are made by 1:1 initiatives. At the same time, limitations of today's tests may have consequences for what and how students are taught using technology (Russell & Higgins, 2003).

One prominent policy problem in the current fiscal and political climate is raising student achievement for certain sub-groups of students, such as those enrolled in special education, members of disadvantaged minority groups, and low-achieving students. Thus, focusing some new studies on student outcomes for selected sub-groups will be important to many policymakers, including some key sponsors of research. Policymakers would surely be interested in high-quality research demonstrating that 1:1 computing initiatives provide valuable benefits for groups of underachieving students and their teachers. Note that research already shows that technology-rich environments are highly engaging for disadvantaged and minority students (e.g., Page, 2002).

To reiterate, conducting research about the impacts of 1:1 initiatives on students' learning is a high priority. However, this should by no means be the only priority for future research. It seems likely that policymakers and the public value 1:1 computing not simply because they expect to raise student achievement but because 1:1 computing promises a wide variety of desirable outcomes, such as nearly instant access to thousands of information sources, easier access by students to online courses not available locally, the replacement of "wet" biology labs with "virtual" dissections, the feasibility of saving time and money by doing more online testing, and increasing motivation for teachers and students, to name just a few benefits that have been discussed in the literature about 1:1 computing. If these sorts of benefits can be achieved at a low enough cost, many policymakers may invest in 1:1 computing whether or not significant student achievement gains are reported.

Documenting Costs

Costs, financial and other, are clearly a major concern for policymakers interested in 1:1 computing. To understand the cost-benefit relationship, we need to identify the variety of benefits of 1:1 computing, as well as the nature and size of the costs, including an appropriate baseline against which to measure those costs.

Few articles or books document the financial costs of 1:1 computing in detail, distinguishing one-time from recurring costs, and providing cost information about professional development, ongoing support, networks, and administration—not just about the computing devices. Researchers could make significant contributions to knowledge in this area soon.

What is the baseline against which to measure the costs of 1:1 computing, whether of handhelds or laptops? Virtually all schools and districts already pay for Internet connections and large numbers of computers, and train teachers to use computing devices for instruction. Billions of dollars are spent for these purposes each year, and that situation is unlikely to change (U.S. Department of Education, Policy and Program Studies Service, 2003). Thus, the cost of adding a 1:1 computing environment is considerably *less* than the cost of supporting all educational technology in schools. This will be just as true in those places that adopt handheld devices for 1:1 computing as in those that adopt laptops.

Initiatives for 1:1 computing also may result in savings as well as in costs. The state of Florida, for example, has considered the potential financial benefit of eliminating dedicated computer labs in high schools by providing every student with a laptop computer (Branigan, 2003). Such a move might obviate the need for construction of expensive, new classroom space. Similarly, many institutions of higher education have reduced costs of print materials by making the same resources available in electronic form, and K-12 schools may be able to do the same, possibly even reducing reliance on textbooks.

Another type of cost study that may be especially useful to policymakers compares more and less dense installations of the same technology. For example, far more schools pay for mobile carts with laptops than provide every student with a laptop. What are the different patterns of use and of outcomes for different densities of computers? Preliminary research on this subject shows that usage increases significantly when every student has a computer (Russell, Bebell, & Higgins, 2004). More research is needed to identify the relative benefits and costs of each approach.

A third type of cost study compares more and less expensive technologies, such as comparing laptops with handheld devices or Danas. Cost studies need to focus on more than just hardware. Research about the most common handheld computing device used in schools, graphing calculators, demonstrates that electronic hardware alone does not change patterns of teaching and learning. Teacher professional development is an essential component of educational technology integration even for this "simple" handheld technology (Burrill et al., 2002). Thus, we can expect that the introduction of any computing devices, including handhelds, will require significant investments in teacher professional development. The more flexible the devices, the greater will be the needed investments in software, school networks, and repair and maintenance. Total cost of ownership requires attention to many details besides the cost of the electronic boxes. We need more information about costs to help policymakers make good decisions, especially expensive decisions affecting large education systems.

Scale and Scaling

Providing computers to every student on a scale of thousands or tens of thousands of individuals is a new phenomenon at the K-12 level. Such initiatives come with major challenges, including deciding what software and services to provide (and paying for them), modifying curricula (where appropriate), maintaining the computers, installing and maintaining the networks (if any), and training the teachers, students and parents. Conducting research on some of the large-scale 1:1 computing initiatives deserves to be a high priority.

Achieving results on a large scale is far more difficult than achieving them in a single classroom or school, and yet it is the results on a large scale that are especially significant to the education system as a whole. Studying the scaling up of complex initiatives in education systems is itself a challenge, quite apart from the focus on technology. Whether it is whole school reform, smaller high schools, or other initiatives, there are significant challenges involved both in successfully demonstrating impacts at a large scale and in studying efforts to do so. A new research literature is emerging about studying scaling up (e.g., Coburn, 2003).

In studies of large-scale 1:1 initiatives, there are many valuable research topics. For some of the large-scale initiatives, it will be important to answer many of the research questions associated with the Implementation and Intermediate Outcomes box in the model in Figure 1.

How are the devices actually used, subject by subject, and grade by grade? Do teaching and instruction change in significant ways, and if so, how? To date, there is not enough detailed information available to convey either typical practices in 1:1 computing environments or outstanding practices. A simple but important contribution to the research literature would be to document, at different grade levels and in different subjects, what expert teachers who use technology effectively have their students do with the technology across a semester or a year.

It is also important to focus on the problems that are being encountered, whether anticipated or unanticipated. Problems might include students accessing inappropriate Internet sites with laptops, or having difficulty entering text data into handheld computers, or teachers not understanding how to make effective use of the computers, as well as many others. What are the problems in a large-scale 1:1 initiative, how serious are they, and how might they be solved?

According to researchers in the field, finding money to support broad studies of large-scale 1:1 computing initiatives has not been easy. For example, money for research often is not included by policymakers when they fund new 1:1 computing initiatives. Nonetheless, there is a critical need for such research. Because large-scale initiatives are so new, there is an unusual opportunity for evidence derived from research to help inform potentially costly choices by policymakers in other locations that are considering 1:1 initiatives.

The Challenge of Rapid Change

The World Wide Web is only about a decade old and is still evolving. "Moore's law," which is the observation (and prediction) that the power of computers double every 18 months while the price stays constant or even diminishes, is likely to remain true for many years to come. As a result, it is safe to say that the power of educational technology used in schools will continue to change rapidly, as will the associated costs. Only recently have thousands of schools and districts been able to adopt wireless networks. Indeed, rapid changes in technology and in associated costs is what has made 1:1 computing initiatives possible.

The rapidity of change makes studying 1-to-1 computing a greater challenge because the potential benefits of educational technology keep changing along with its power. For example, the teaching of foreign languages may be revolutionized as it becomes feasible for students to cheaply and easily send and receive audio and video files electronically, including recordings of their own voice. Advocates of some handheld devices point to the potential benefits of using relatively inexpensive classroom networks in new ways that allow teachers to almost instantly understand how well students are learning new concepts (e.g., Roschelle & Pea, 2002). Some districts are already eliminating collections of videotapes and distributing "instructional video" entirely through local networks, thereby saving money and making more efficient use of their video collections. Parental involvement in schools may improve as more and more districts provide computerized access for parents to students' assignments, grades, transcripts, attendance records, and to their teachers.

The research community needs to keep one eye on new technologies and potential new benefits of 1:1 computing at the same time that it works to solidify research and development on such by-now "traditional" applications of computers as to improve students' reading, writing, and mathematics skills. To a degree, this is asking the R&D community to help redesign the education system while it continues functioning—and to evaluate it at the same time.

Researchers and policymakers alike need to distinguish between studies designed to support development and testing of new technologies and those that focus on more mature technologies. Both types of research are needed. However, until new technologies have been proven on a large scale, findings about them should be viewed as work-in-progress. Similarly, it will be important to document the persistence of effects of 1:1 computing over time, and not only what happens during the first year or two.

Measurement Challenges

The cost of accurately gathering data about tens of variables is great. What is more, the nature of the data to be gathered is not always clear. How, exactly, would one set out to rigorously "prove" that 1:1 computing in Maine is responsible for increased economic development in the state—and not a rising stock market, or geographic population shifts, or other state and federal policies? If students' motivation and attendance increase as a result of a 1:1 computing initiative, would we necessarily expect scores on standardized tests to increase—and even if they did, wouldn't we want to measure motivation and attendance as well as test scores? What are appropriate and accepted measures of so-called 21st-century skills, including the use of modern electronic tools such as spreadsheets, word processors, and Internet search engines?

Even if measurement problems are solved and a wide range of data becomes available, how would researchers "add up" the disparate number of positive and negative outcomes of 1:1 computing? It seems clear that some researchers will focus on one or just a few outcomes at a time, especially if they use the most rigorous designs, such as randomized experimental trials. Yet researchers who study many variables, for example through surveys, can also provide very important information, but cannot offer as much confidence about causality.

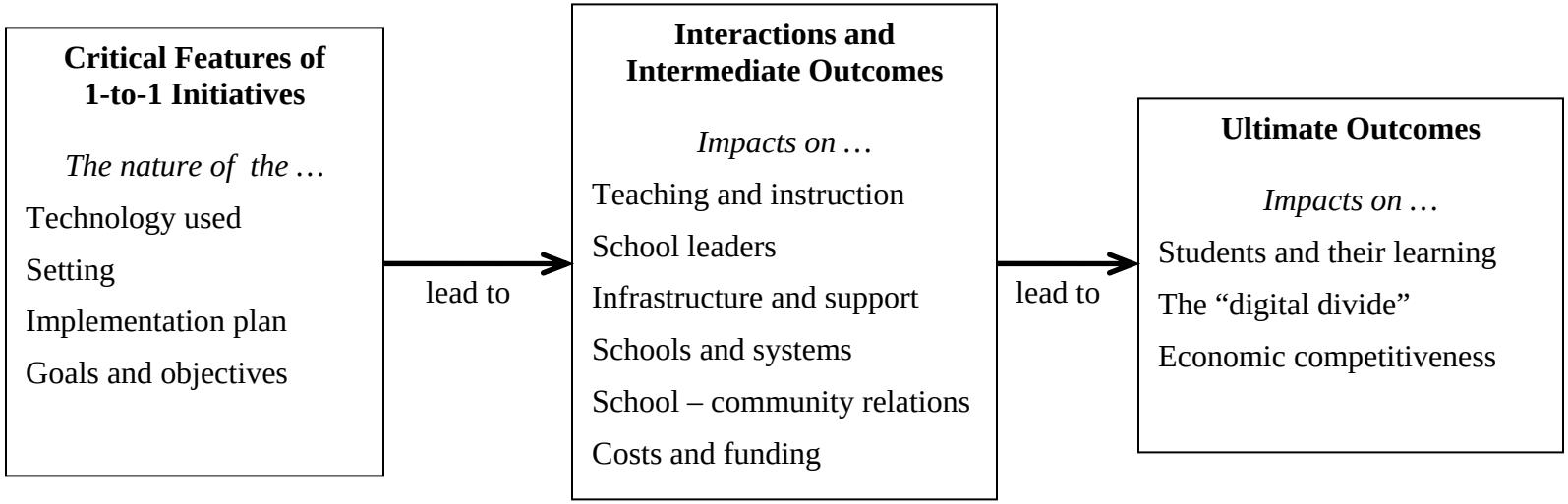
Perhaps the value of 1:1 computing initiatives does not lie mainly in a small number of major benefits, such as raising test scores in core academic subjects. Instead, as seems increasingly likely, the benefits of 1:1 computing may come in numerous forms, many of which are difficult to quantify, and no one of which is sufficient to justify the investment. Yet, in total, the multiple benefits of 1:1 computing may provide students and the public with substantial value—enough to justify the sizable investments that are necessary to provide every teacher and student with a computer.

Conclusion

The responsibility to integrate scattered and sometimes contradictory research findings and to decide how to spend education dollars rests with the public and key policymakers. With limited research available, their judgment is especially critical.

Still, good evidence contributes to good judgment. Amidst calls for more scientifically-based research in education, the subject of 1:1 computing deserves more research dollars. Tens of billions of dollars of public funds will be spent on educational technology in the United States during the coming years, and an increasing portion of those funds will be spent for 1:1 initiatives. More and better research, carefully targeted to answer high-priority research questions, will help guide both policy and practice.

Figure 1: A Framework for Research on 1:1 Computing



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